Task 2 Report – Material-Level Evaluation

Exploration of UHPC Applications for Montana Bridges

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1 Introduction

Past and current research into ultra-high performance concrete (UHPC) at Montana State University has been focused on: (1) developing a nonproprietary mix design (MT-UHPC), (2) evaluating the sensitivity, durability and mechanical properties of this mix, (3) investigating its use in field-cast joints, and (4) implementing this mix in a bridge project in Montana. This research discussed herein is focused on exploring potential future bridge applications of UHPC in Montana, beyond its use in field-cast joints.

The specific tasks associated with this research are as follows:

Task 0 – Project Management

Task 1 – Literature Review

Task 2 – Material-Level Evaluation

Intermediate Technical Panel Meeting Task

Task 3 – Experimental Design of Structural Testing

Task 4 – Structural Testing

Task 5 – Analysis of Results and Reporting

This report documents the work completed as part of Task 2 – Material-Level Evaluation. It should be noted that while the future direction of this research may explore using UHPC to repair/rehabilitate steel or wood elements, the material-level research thus far has focused primarily on its use to repair concrete elements, as this application has shown some of the most promise. Confidence in the use of UHPC as a strengthening material for concrete elements requires the exploration of surface preparations and the subsequent bond strengths between the UHPC and standard concrete.

This task was focused on evaluating the performance of three different UHPC mixes for the desired concrete repair/overlay application. Specifically, this task investigated the workability of these mixes, and tested the compressive, tensile and bond strengths of these concretes. The mixes investigated in this research included MT-UHPC, MT-UHPC with the addition of a viscosity modifying admixture for thixotropy, and a proprietary thixotropic Ductal mix. This report first discusses the mix designs and constituent materials, followed by a description of the testing program. The results from the tests are then presented and discussed.

This report, in addition to Task 1 Report – Literature Review, will be used to guide discussions during the Intermediate Technical Panel Meeting to ultimately decide the direction of the structural testing portion of this research (Tasks 3 and 4).

2 Materials

Three UHPC mixes were investigated at the material level to evaluate compressive and tensile strength, and the bond strength with substrate concrete. The mixes include MT-UHPC, MT-UHPC with the addition of a viscosity modifying admixture for thixotropy (designated here as MT-UHPC-T), and a proprietary thixotropic Ductal mix (designated here as Ductal-T). In this section, first the substrate conventional concrete is discussed, followed by a discussion of each UHPC mix. It is important to note that trial batches were performed for the MT-UHPC-T and Ductal-T mixes to determine admixture/water dosages; however, specific details on these trial batches are not included in this report.

2.1 Substrate Concrete

The substrate concrete mix was a conventional 4 ksi design strength mix targeting 3% air entrainment. The mix design for a 3-ft^3 batch is shown below in Table 1. The substrate concrete was mixed in a standard rotating-drum, fixed-vane mixer. The coarse and fine aggregate and approximately 4 pounds of the water were added first and mixed for 3 minutes. Once the aggregates reached saturated surface dry (SSD) condition, the air entraining admixture was added, and the aggregates were mixed for 2 additional minutes. The water and cement were then added simultaneously and mixed for approximately 8 minutes. A slump test was performed for each mix in accordance with ASTM C143 and an average slump of 2" was measured.

This concrete mix was used as the substrate concrete for the bond tests completed for each of the UHPC mixes tested in this research. These tests will be discussed in detail in a later section.

Table 1: Substrate concrete mix design for a 3 ft^3 batch

Item	Weight (lbs)
Water	37.6
MasterAir AE 200	13.67 (ml)
Cement	68.4
Coarse Aggregate	218.7
Fine Aggregate	116.2

2.2 MT-UHPC

The standard MT-UHPC mix was developed in previous research at MSU. The mix design for a 3-ft^3 batch is shown in Table 2. A fixed-drum, rotating fin high-shear mortar mixer (IMER Mortarman 360) was used to mix the MT-UHPC using the procedures developed in previous research. This procedure involved adding the fine aggregate and silica fume first and mixing for 5 minutes. Cement and fly ash were added next and mixed for an additional 5 minutes. The premixed water and HRWR were then added to the mixer. The mix took approximately 15 minutes to turn over and become fluid. The steel fibers were then added and mixed for 3 minutes. A static flow test was performed following ASTM C1856 and a flow of 10.25" was measured as shown in Figure 1.

Table 2: MT-UHPC mix design for a 3 ft^3 batch

Item	Weight (lbs)
Water	33.2
CHRYSO Fluid Premia 150 (HRWR)	7.2
Steel Fibers	29.2
Cement	144.4
Silica Fume	30.9
Fly Ash	41.3
Fine Aggregate	172.9

Figure 1: MT-UHPC static flow test

2.3 MT-UHPC-T

The MT-UHPC-T mix was identical to the standard MT-UHPC mix, with the exception of the viscosity modifying admixture. The mix design for a 3-ft^3 batch is shown in Table 3. The viscosity modifying admixture was MasterMatrix UW 450 (spec sheet included in Appendix A). A total of 15 fluid ounces of this admixture was used in the 3-ft^3 batch, which equates to a dosage rate of 6.9 fluid ounces per 100 lbs of cementitious materials (6.9 fl oz/cwt). A fixed-drum, rotating fin high-shear mortar mixer (IMER Mortarman 360) was used to mix the MT-UHPC-T, using a procedure similar to that used for the standard MT-UHPC. After adding the HRWR it took over 15 minutes for the mix to turn over. Once the fibers were thoroughly mixed, the MasterMatrix UW 450 admixture was added and mixed for 5 minutes. The static and dynamic flows were measured at 4.0" and 5.5", respectively (Figure 2). The dynamic flow was slightly lower than desired; however, the consistency of the mix was appropriate, and the mix performed well. This was the first large-scale batch of a thixotropic version of MT-UHPC, and although some adjustments may be warranted to optimize the flows, the results are promising.

Table 3: MT-UHPC-T mix design for a 3-ft^3 batch

Item	Weight (lbs)
Water	33.2
CHRYSO Fluid Premia 150 (HRWR)	7.2
Steel Fibers	29.2
Cement	144.4
Silica Fume	30.9
Fly Ash	41.3
Fine Aggregate	172.9
MasterMatrix UW 450	15 (oz)

Figure 2: MT-UHPC-T static (left) and dynamic (right) flow test results

2.4 Ductal-T

Materials and mix proportions were provided by LafargeHolcim for the Ductal-T UHPC mix. The mix design for a 3-ft^3 batch is shown in Table 4.

Table 4: Ductal-T mix design for a 3 ft^3 batch

Item	Weight (lbs)
Water	31.8
F5 Admixture	4.1
Steel Fibers	46.5
Ductal Premix	375.0

Again, the IMER Mortarman 360 mixer was used to mix the material. The dry ingredients were added to the mixer first and mixed for 3 minutes to ensure that the mix was homogenized. The water was then added, and immediately followed by the F5 admixture. After 4 minutes of mixing, the mix began to turn over, and after an additional 3 minutes the mix had fully turned over and the steel fibers were added. The fibers were then mixed in for 3 minutes. An initial dynamic flow was measured at 6”. This was slightly lower than the desired dynamic flow of 6.25”-7.25” (as recommended by LafargeHolcim). An additional 1.35 lbs (already accounted for in Table 4) of water was then added and mixed for 2 minutes. A new dynamic flow test was performed and a flow of 6.5” was recorded (Figure 3). A static flow of 4” was also recorded.

Figure 3: Dynamic flow test results for Ductal-T

3 Experimental Design

This research consisted of testing the compressive, tensile, and bond strength of three UHPC materials. This section discusses details on the tests used to evaluate these properties. Specifically, general compressive and tensile test methods are discussed, followed by detailed descriptions of the direct-tension and slant-shear bond tests.

3.1 Compressive and Tensile Testing

Compressive strength testing was performed per ASTM C1856 and ASTM C39 for the UHPC and substrate concrete mixes, respectively. Compressive strengths for the UHPC materials were obtained at 7, 14, and 28 days, while compressive strengths for the substrate concrete were only obtained on the day that the direct tension and slant shear tests were performed. Flexural strength testing was performed at 28 days in substantial accordance with ASTM C1609 on 20”x6”x6” prisms. A typical flexural specimen in the load frame is shown in Figure 4.

It should be noted that these test specimens were prepared following procedures outlined in previous MSU research [1]. However, additional procedures were required to consolidate the thixotropic mixes. Specifically, these specimens were placed on a vibration table during casting.

Figure 4: Example flexural test performed on a Ductal-T specimen

3.2 Direct Tension Testing

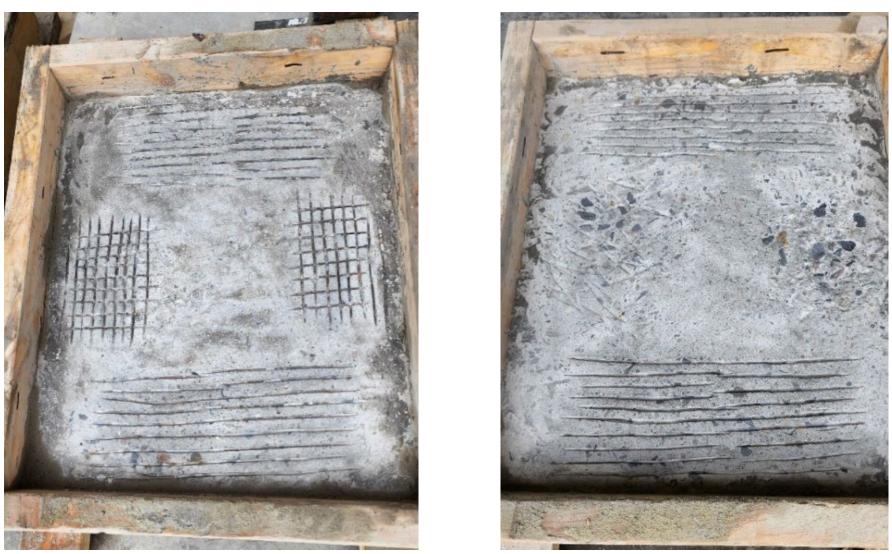
Direct tension testing was performed by following similar procedures outlined in ASTM C1583 Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method). This testing determines a limit on the tensile bond strength between standard concrete and the UHPC mixes and is dependent on the substrate concrete surface preparation. In this test, failures will typically occur either at the bond between the two materials, in the substrate concrete, or in the adhesive between the core and test fixture. This test is typically conducted in the field on in-place slabs by pulling directly on cores from the slab and recording the maximum pulling force. In this research, due to availability of equipment, small test slabs with UHPC overlays were constructed in the lab, and cores were extracted and tested in direct tension with an MTS compression/tension load frame.

The slab specimens were 23”x19.25” and were constructed first with 3” of normal substrate concrete (Figure 5). Two substrate slabs were constructed for each of the three UHPC mixes, for a total of six slabs.

The substrate concrete slabs were cured in the cure room for at least 28 days. After curing, the surfaces of the slabs were prepared using an angle grinder. After first grinding the top surface flat, three different surface preparation techniques were explored to examine the efficacy of each of these methods. The first method, which is designated as typical (T) included parallel grooves in one direction that were ¼” deep and ⅛” wide and spaced at ½” intervals (Figure 6a and Figure 7a). The second method was designated as cross-hatch (XH), and consisted of grooves of the same size as those designated for T, but in both directions (Figure 6a and Figure 7b). The final method was designated as chipped (C) and consisted of a jack-hammered surface with an approximate roughness of ¼" (Figure 6b and Figure 7c).

It should be noted that the surface roughness achieved for the T specimens should yield conservative results, as surface preparation techniques used in the field are typically more aggressive than this, with a minimum specified texture depth of ¼” according to ACI recommendations for conventional concrete repair [2]. Therefore, the T specimens will provide for a conservative limit on bond strength, while the cross-hatch and chipped specimens will provide more data for discussion.

Figure 5: Typical substrate concrete slabs for direct tension specimens



a) T and XH b) T and C

Figure 6: Substrate surface preparations for direct tension testing

a) T Surface Preparation b) XH Surface Preparation c) C Surface Preparation

Figure 7: Close-up views of surface preparation methods

After preparation, 1.75” of UHPC was placed on top of the prepped slab surfaces. The substrate surfaces were typically wetted with a sponge prior to the placement of the UHPC. However, one of the Ductal-T slabs was not wetted prior to placement, which had a significant effect on performance, as will be discussed in a later section. After placement of the thixotropic UHPC mixes, the slabs were then consolidated by placing the slab on the vibration table and vibrating for several seconds while tapping with a rubber mallet (as shown in Figure 8).

Figure 8: Typical consolidation process for thixotropic specimens including shake table (located below specimen form) and external tapping with rubber mallet

After curing, the slabs were then cored to extract the direct-tension specimens (Figure 9). This coring was done using a Diamond Products Core Bore 748 drill, with a 2” inner diameter Husqvarna diamond core drill bit (Figure 9b). The cores were drilled through the slabs, and then cut to length. Typically, at least 1.5” of UHPC and substrate concrete was desired, though some samples were cut shorter due to a slightly thinner overlay. Overall, 11 successful core specimens were extracted for MT-UHPC (8T, 2XH, and 1C), 8 cores for MT-UHPC-T (6T and 2XH), and 11 cores for Ductal-T (8T, 2XH, and 1C). After extraction, the cores were then epoxied to two 2” diameter, 1” thick steel discs (one on each end) using Simpson Strong-Tie SET-XP epoxy (Figure 9d). Note that the slab in Figure 9c is in the same orientation as the surface preparations shown in Figure 6.


a) Cured slab before coring b) Core drill in place on slab


c) Slab after coring d) Core prepped for testing

Figure 9: Typical direct tension core specimen preparation

After preparation, the specimens were tested in an MTS compression/tension load frame, as shown in Figure 10. As can be seen in the figure, the test fixture consisted of a series of shackles and eyebolts to ensure proper alignment and alleviate any potential eccentricities introduced as a result of support fixity. The ultimate tensile bond strength was then calculated by dividing the ultimate load by the cross-sectional area of the specimen.

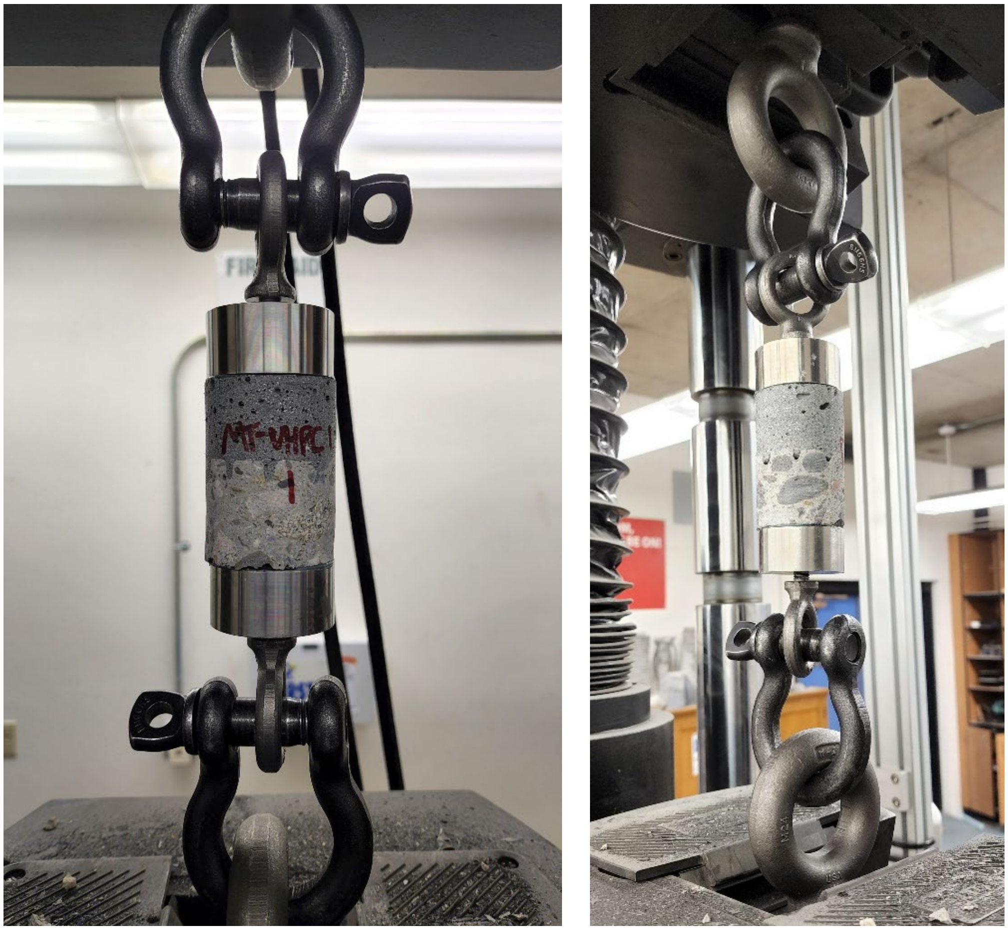


Figure 10: Example direct tension specimens prior to testing

3.3 Slant Shear Testing

Shear bond strength is a critical parameter needed to fully assess the bonding of UHPC to standard concrete for a range of potential applications. In this research, this property was tested with slant shear tests. These tests were performed in substantial accordance with ASTM C882 Standard Test Method for Bond Strength of Epoxy-Resin Systems Used with Concrete by Slant Shear. Typically, failures will occur either at the bond between the two materials or in the substrate concrete.

To adapt the ASTM standard for testing UHPC, 4”x8” cylinders were cast instead of the recommended 3”x6”. This was done to accommodate the size of the coarse aggregate in the substrate concrete and to allow for a larger surface area for preparation. For placement of the substrate concrete, wood forms were used to rotate the cylinders 30-degrees, as shown in Figure 11. After initial curing, the substrate concrete was removed from the molds and placed into the cure room. After at least 28 days, the samples were removed from the cure room and the top surface of the incline was grooved to simulate surface preparation that may take place prior to UHPC placement. The same “typical” surface preparation discussed for direct tension testing was investigated for slant shear. Specifically, an angle grinder was used to grind the top surface flat and apply grooves ¼” deep, ⅛” wide, at ½” spacing on the inclined surface (Figure 12a). To assess the worst-case scenario, the grooves were aligned parallel with the direction of the shear loading.

Figure 11: Typical substrate concrete half cylinders for slant shear specimens

After curing and surface preparation, the slant shear substrate concrete samples were then placed back into the 4"x8" cylinder molds in order to place the various UHPC mixes (Figure 12b). The top surfaces of the substrate concrete were wetted prior to placement of the UHPC. At 24 hours after UHPC placement, the cylinders were removed from the molds, and the ends of the cylinders containing UHPC were ground to level the surface and prepare for testing. These specimens were then placed into the cure room until testing. After curing, these specimens were then tested in compression according to ASTM C39 (per ASTM C882), as shown in Figure 13. The ultimate bond shear stress was then calculated by dividing the recorded maximum load by the area of the bond surface.

a) Substrate half cylinder with surface prepped

b) Prepped substrate in cylinders

Figure 12: Typical slant-shear specimen preparation prior to UHPC placement

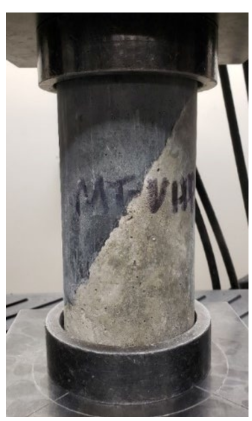


Figure 13: Slant-shear specimen in load frame

4 Test Results

4.1 Compressive and Tensile Strengths

The average compressive and tensile strengths of the various UHPC at 7, 14, and 28 days are provided Table 5, along with the measured and predicted flexural strengths at 28 days. The compressive and tensile averages were calculated from the results of 3-5 cylinders and 2-3 prisms, respectively. Included in this table are the dynamic and static flows recorded for each UHPC mix. As expected, compressive strength increased with time for all UHPC mixes. The MT-UHPC mix and the Ductal-T mix both reached 28-day compressive and tensile strengths of around 17 ksi and 3.4 ksi, respectively. The MT-UHPC-T mix was observed to have the lowest compressive and tensile strengths (15.4 ksi and 2.8 ksi); however, these strengths are still in line with those expected for UHPC. As previously mentioned, this was the first large-scale batch of a thixotropic MT-UHPC, and further research may be warranted to optimize the admixture dosages, which could have a positive effect on strength.

Regarding ultimate tensile strengths, the strengths are on par with past research on this material. For reference, this table also includes estimates of the tensile strength based on the compressive strength of the material. Specifically, the tensile strengths were predicted as $f_r = 7.5\sqrt{f'_c}$ with f_r and f'_c in psi. As can be observed in this table, the measured tensile strengths are at least three times the predicted values. However, it should be noted that the tensile stress calculated at ultimate load is for comparative purposes, as the equation used to calculate this stress from applied load assumes no cracking and linear-elastic behavior, which is not the case at ultimate load.

Table 5: Average compression and flexure test results

	Flow (in)		Compressive Strength, f'c (ksi)			Ultimate Tensile Strength (ksi)		
UHPC Type	Static	Dynamic	7-Day	14-Day	28-Day	Measured	Predicted	Meas/Pred
MT-UHPC	10.25	-	14.3	15.1	17	3.37	0.978	3.45
MT-UHPC-T	4	5.5	11.6	-	15.4	2.8	0.931	3.01
Ductal-T	4	6.5	15.1	17.3	17.4	3.43	0.989	3.47

4.2 Direct Tension Results

The average compressive strengths on the day of testing are provided in Table 6 for the substrate concrete and the UHPC. It should be noted that the MT-UHPC-T specimens were tested 7 days after casting the UHPC and the specimens for the other two mixes were tested 14 days after casting the UHPC. The results from the direct tension tests are provided in Table 7, including the averages and coefficients of variation (CoV) observed for each surface preparation method. Each specimen failed at either the bond between the two materials (Figure 14) or in the substrate concrete (Figure 15). The asterisks in the table indicate what type of failure was observed for each specimen. It should be noted that if the specimen failed in the substrate concrete prior to bond failure the actual ultimate tensile bond strength is unknown, and therefore the value provided in the table can be interpreted as a minimum value. It should be noted that some of the core specimens extracted from the slabs were not viable for testing due to incidental damage or poor consolidation, hence the varied number of specimens.

Table 6: Average concrete strengths for direct tension testing

UHPC Type	Substrate Compression (ksi)	UHPC Compression (ksi)
MT-UHPC	5.4	15.1
MT-UHPC-T	5.2	11.6
Ductal-T	5.4	17.3

Table 7: Direct tension results for all specimens

Groove Pattern	Sample Number	MT-UHPC (psi)	MT-UHPC-T (psi)	Ductal-T (psi)	
				Wet	Dry
Typical	T1	280**	239*	197*	60*
	T2	210**	146*	332*	11*
	T3	256**	291*	433*	15*
	T4	251*	192*	367**	106*
	T5	206**	208*	-	-
	T6	234*	-	-	-
	Average	239	215	333	48
	CoV	10.90%	22.60%	25.90%	81.20%
Crosshatch	XH1	220*	148*	343*	-
	XH2	234*	161*	297*	-
	Average	227	155	320	
	CoV	3.20%	4.20%	7.10%	-
Chipped	C1	252**	-	234**	-

*Bond Failure

**Substrate Concrete Failure

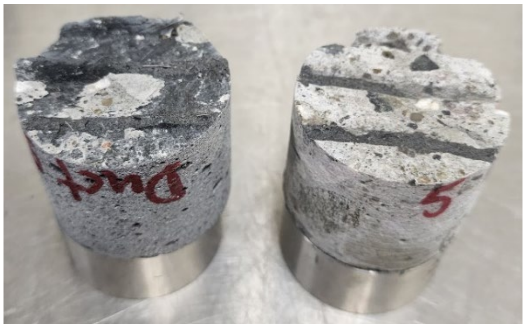


Figure 14: Example direct tension failure at the bond (Ductal-T Wet T1)

Figure 15: Example direct tension failure in the substrate concrete (MT-UHPC T2)

As can be seen in Table 7, the average bond strength limits for all specimens ranged from 155 to 333 psi regardless of the surface preparation method (sans the dry substrate preparation), which is above the ACI recommendations of 150 psi for concrete repair [2].

To facilitate a comparison between the different UHPC mixes, the average tensile stresses for the T specimens are shown in Figure 16 for each UHPC mix type. As can be observed in this figure, both MT-UHPC mixes had similar tensile strengths with the conventional MT-UHPC slightly outperforming the thixotropic mix. The Ductal-T performed the best, with strengths approximately 40% higher than those observed for the other two mixes.

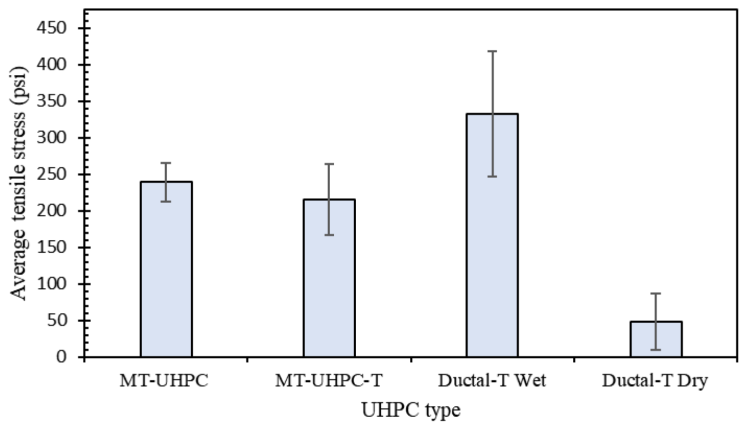


Figure 16: Average peak tensile stresses of typical (T) direct tension specimens (error bars represent one standard deviation).

Regarding the effects of surface preparation methods, the results for the dry Ductal-T specimens highlight the importance of wetting the surface of the substrate concrete prior to UHPC placement, as the average bond strengths observed for these specimens was only 48 psi. Further, for MT-UHPC and Ductal-T, the bond strengths observed for the XH specimens were slightly less than those observed for the T specimens, indicating that this surface preparation does not improve the bond between the layers. The results of the XH specimen for MT-UHPC-T were significantly less than the T specimens, most likely due to the poor consolidation and further highlighting the need to fine-tune the admixture dosage. Similarly, the effect of "chipping" the concrete was shown to have mixed results (increases capacity for one type of concrete, while reducing it for the other).

4.3 Slant Shear Results

The slant shear specimens for all UHPC mixes were tested 7 days after casting the UHPC. The average compressive strengths on the day of testing are provided in Table 8, while the measured minimum bond shear strengths are provided in Table 9. Note that all specimens were observed to fail in compression in the substrate concrete (Figure 17), sans one specimen that failed at the interface between the substrate concrete and Ductal-T (Figure 18). Because nearly all specimens failed in the substrate concrete prior to the bond failing, the actual bond shear stress was not obtained, and the values reported here can be interpreted as the minimum bond shear stress. It should be noted that all minimum bond shear stresses were nearly 3 ksi, which far exceeds the ACI specified minimum of 1 ksi [2]. This, despite the surface preparations being parallel to the loading direction, a conservative alignment. To obtain the actual bond stress, future testing could consider wrapping the substrate concrete with fiber reinforced polymer to force the failure to the bond surface.

Table 8: Average concrete strengths for slant shear testing

UHPC Type	Substrate Compression (ksi)	UHPC Compression (ksi)
MT-UHPC	5.4	14.3
MT-UHPC-T	5.2	11.6
Ductal-T	5.6	15.1

Table 9: Slant shear results for all specimens

Sample Number	Minimum Bond Shear Strength (ksi)		
	MT-UHPC	MT-UHPC-T	Ductal-T
1	2.94	3.15	3.13*
2	2.77	3.33	3.26
3	2.75	3.31	3.3
4	2.82	3.37	3.16
Average	2.82	3.29	3.24
CoV	3.02%	2.94%	2.23%

*Bond Failure

a) MT-UHPC-T 1 b) MT-UHPC 2

Figure 17: Example slant shear failures in the substrate concrete

Figure 18: One specimen with a slant shear failure at the bond (Ductal-T 1)

5 Summary and Conclusions

This report documents the work completed as part of Task 2 – Material-Level Evaluation of the MDT/MSU research project Exploration of UHPC Applications for Montana Bridges. Three UHPC mixes were investigated, including 1) MT-UHPC, 2) MT-UHPC with the addition of a viscosity changing admixture for thixotropy, and 3) a proprietary thixotropic version of Ductal. The workability, and compressive and tensile strengths were evaluated first, followed by direct tension and slant shear bond tests with varying surface preparation methods. Based on this evaluation, the following conclusions can be made.

- The three UHPC mixes tested in this research had adequate compressive and tensile strengths, in line with previous research on UHPC. The MT-UHPC conventional mix and the Ductal-T mix had 28-day compressive and tensile strengths of around 17 ksi and 3.4 ksi, respectively. The thixotropic MT-UHPC had slightly less strength at 28 days, with compressive and tensile strengths of around 15 ksi and 2.8 ksi, respectively. While these strengths were slightly less, it is important to note that this was the first large-scale batch of this material, and higher strengths may be acquired if this mix is refined.
- The two thixotropic mixes investigated in this research (MT-UHPC-T and Ductal-T) had appropriate flows for the desired overlay application, where a stiffer mix is required for placement on graded/crowned bridges. The MT-UHPC-T had static and dynamic flows of 4” and 5.5”, while the Ductal-T mix had static and dynamic flows of 4” and 6.5”. The dynamic flow of the MT-UHPC-T mix is slightly low, but again this is the first large-scale batch of this material, and better flows may be acquired with some refinement.
- The direct-tension bond tests for all three concretes and nearly all surface preparation methods reached the minimum strength specified by ACI for concrete repairs. The only specimens that did not meet this minimum were the Ductal-T specimens in which the surface of the substrate concrete was not wetted prior to placement of the UHPC overlay, highlighting the importance of this step.
- The minimum bond strengths obtained from the slant-shear tests for all concretes met the ACI specified shear bond for concrete repairs. This, despite a conservative surface preparation method with grooves parallel to the loading direction. Also, it is important to point out that all but one specimen failed due to concrete crushing in the substrate concrete, and therefore the actual bond stresses at failure were not obtained and the recorded values can be interpreted as minimum values.
- For many of the direct-tension tests and nearly all of the slant-shear tests the specimens failed in the substrate concrete prior to the bond failure, and therefore the recorded bond strengths can be interpreted as minimum values. Future research could modify these tests to ensure failure in the bond. For example, the substrate concrete in the slant shear tests could be wrapped with FRP prior to testing to ensure that this concrete does not fail prematurely in compression.

6 References

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2. ACI Committee 546R-04: *Guide to Materials Selection for Concrete Repair*, American Concrete Institute ACI546R-04, 2004.

Appendix A: MasterMatrix UW 450 Spec Sheet

3 | 03 30 00 Cast-in-Place Concrete
03 37 26 Underwater Placed Concrete

MASTER®
» BUILDERS
SOLUTIONS

MasterMatrix® UW 450
Anti-Washout Admixture

Description

MasterMatrix UW 450 anti-washout admixture is a patented, ready-to-use, liquid cellulose-based admixture that is specially developed for underwater concrete applications. Concrete containing MasterMatrix UW 450 admixture exhibits superior resistance to washout of cement and fines, while impeding the blending of external water into the plastic concrete.

MasterMatrix UW 450 admixture meets the requirements of the U.S. Army Corps of Engineers CRD-C661-06,Specification for Anti-Washout Admixtures for Concrete.

Applications

Recommended for use in:

- All types of underwater concreting where conventional concrete or placing techniques would result in a high percentage of material loss due to washout
- Mortar and grouting applications where mixtures are typically more fluid and have a higher potential for washout

Features

- Reduction in washout of cement and fines
- Reduction in segregation, even with highly fluid, high water-to-cementitious materials ratio concrete mixtures
- Thixotropic action that provides concrete stiffening after placement
- Reduction or elimination of concrete bleeding

Benefits

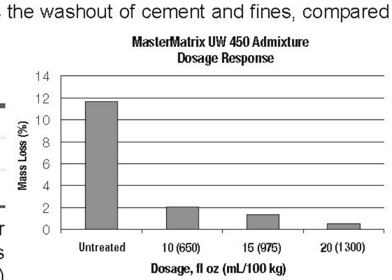
- Superior and predictable in-place concrete properties
- Dewatering costs reduced/eliminated
- Environmental impact of cement washout in water minimized
- Flexibility in batching procedures

Performance Characteristics

Washout Resistance: Washout is determined by Army Corps of Engineers CRD-C 61, "Test Method for Determining the Resistance of Freshly Mixed Concrete to Washing Out in Water". Test results show that the addition of MasterMatrix UW 450 anti-washout admixture to concrete significantly reduces the washout of cement and fines, compared to untreated concrete.

Concrete Mixture Data (Non-Air-Entrained Concrete)

Cement Content	650 lb/yd³ (386 kg/m³)
Water-Cement Ratio	0.49
Slump	4 ± 0.5 in. (100 ± 10mm)



Slump: Concrete that is designed for underwater placement applications is typically batched at an 8-10 in. (200-250 mm) slump. After MasterMatrix UW 450 admixture is added, a decrease in slump will be noted. It may be necessary to add additional high-range water-reducing admixture to achieve the slump required for placement. Slump evaluations for a 60-minute period show that MasterMatrix UW 450 admixture does not adversely affect concrete slump retention.

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Air Content: A slightly higher dosage of air-entraining admixture may be required to achieve the desired air content when using MasterMatrix UW 450 admixture.

Setting Time: MasterMatrix UW 450 admixture has little to no effect on concrete setting time at commonly used dosages of 4-12 fl oz/cwt (260-780 mL/100 kg). Slight retardation of setting time may be experienced at dosages over 12 fl oz/cwt (780 mL/100 kg).

Compressive Strength: Using test specimens that are cast in air, concrete containing MasterMatrix UW 450 admixture may obtain slightly lower compressive strength when compared to untreated concrete. However, when strength is evaluated using test specimens that are cast underwater, concrete containing MasterMatrix UW 450 admixture achieves higher strength because washout is minimized. In addition, most underwater concrete mixtures that are proportioned in accordance with ACI 304R, "Guide for Measuring, Mixing, Transporting, and Placing Concrete", exceed compressive strengths that are required for underwater applications. If necessary, a lower water-to-cementitious materials ratio may be used to achieve the desired results.

Guidelines for Use

Dosage: MasterMatrix UW 450 admixture is recommended for use at a dosage range of 4-20 fl oz/cwt (260-1300 mL/100 kg) of cementitious materials for most concrete mixtures. Because of variations in concrete materials, jobsite conditions and/or applications, dosages outside of the recommended range may be required.

Mixing: For underwater concrete placements, ACI 304R, Chapter 8, "Concrete Placed Underwater" provides certain basic mixture proportions such as:

- A minimum total cementitious material content of 600 lb/yd^3 (356 kg/m^3)
- Use of pozzolans approximately 15% by mass of cementitious materials
- A maximum water-to-cementitious materials ratio of 0.45
- Fine aggregate contents of 45-55% by volume of total aggregate
- Air contents of up to 5% are listed as desirable
- A slump of 6-9 in. (150-230 mm) is generally necessary and occasionally a slightly higher slump range is needed

MasterMatrix UW 450 admixture should be added with a water-reducing admixture, such as Master Builders Solutions MasterPolyheed® or MasterSet® admixture lines. For achieving high slump concrete, use MasterMatrix UW 450 admixture in conjunction with a MasterGlenium® high-range water-reducing admixture. This combination will produce a high-performance, flowing concrete that exhibits superior resistance to washout of cement and fines. MasterMatrix UW 450 admixture should be added after all other concreting ingredients have been batched and thoroughly mixed, either at the batch plant or at the jobsite.

Concrete Placement: Concrete containing MasterMatrix UW 450 admixture is easily pumped throughout the typical slump ranges that are used for underwater concreting. It is recommended that concrete containing MasterMatrix UW 450 admixture is placed by pump or tremie. Concrete placement should be continuous and without interruption. Keep the discharge point of the placement device immersed in the fresh concrete during placement.

It is not recommended that concrete containing MasterMatrix UW 450 admixture be allowed to free-fall through water during placement.

Product Notes

Corrosivity – Non-Chloride, Non-Corrosive: MasterMatrix UW 450 admixture will neither initiate nor promote corrosion of reinforcing and prestressing steel embedded in concrete, or of galvanized steel floor and roof systems. Neither calcium chloride nor other chloride-based ingredients are used in the manufacture of this admixture.

Compatibility: Do not use MasterMatrix UW 450 admixture with naphthalene-based high-range water-reducing admixtures. Erratic behaviors in slump, pumpability and washout may be experienced.

Storage and Handling

Storage Temperature: MasterMatrix UW 450 admixture must be stored at temperatures above 44 °F (7 °C) to avoid dispensing difficulties due to thickening. Do not allow MasterMatrix UW 450 admixture to freeze since it cannot be reconstituted after thawing.

Shelf Life: MasterMatrix UW 450 admixture has a minimum shelf life of 12 months. Depending on storage conditions, the shelf life may be greater than stated. Please contact your local sales representative regarding suitability for use and dosage recommendations if the shelf life of MasterMatrix UW 450 admixture has been exceeded.

Handling: Contact with water in hoses, pumps, tanks or receiving vessels must be avoided to prevent gelling when transferring MasterMatrix UW 450 admixture to other containers.

Dispensing: Consult your local sales representative for the proper dispensing equipment for MasterMatrix UW 450 admixture. If dispensing directly from the 55 gal (208 L) drum, it is recommended that the larger 2 in. (50 mm) opening be used.

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Packaging

MasterMatrix UW 450 admixture is supplied in 53 gal (201 L) drums and 264 gal (999 L) totes.

Related Documents

Safety Data Sheets: MasterMatrix UW 450 admixture

Additional Information

For additional information on MasterMatrix UW 450 admixture or its use in developing concrete mixtures with special performance characteristics, contact your local sales representative.

Master Builders Solutions, a brand of MBCC Group, is a global leader of innovative chemistry systems and formulations for construction, maintenance, repair and restoration of structures. The Admixture Systems business provides advanced products, solutions and expertise that improve durability, water resistance, energy efficiency, safety, sustainability and aesthetics of concrete structures, above and below ground, helping customers to achieve reduced operating costs, improved efficiency and enhanced finished products.

Utilizing worldwide resources, the Master Builders Solutions community of experts are passionate about providing solutions to challenges within all stages of construction, as well as the life cycle of a structure. At Master Builders Solutions we create sustainable solutions for construction around the globe.

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